NON-CONSECUTIVE TRANSITIONAL MECHANISM FOR SEEK OPERATIONS WHEN TRANSITIONING FROM A SEEK CONTROL TO A TRACK FOLLOWING CONTROL

Field of the Invention

The present invention relates generally to the field of seek operation control in a disc drive. More particularly, the present invention relates to an apparatus and method for performing transitional control of a read/write head when the seek operation is transitioning from seek control to a track following control.

Background of the Invention

Disc drives are commonly used in workstations, personal computers, laptops and other computer systems to store large amounts of data in a form that can be made readily available to a user. In general, a disc drive comprises a magnetic disc that is rotated by a spindle motor. The surface of the disc is divided into a series of data tracks. The data tracks are spaced radially from one another across a band having an inner diameter and an outer diameter.

Each of the data tracks extends generally circumferentially around the disc and can store data in the form of magnetic transitions within the radial extent of the track on the disc surface. An interactive element, such as a magnetic transducer, is used to sense the magnetic transitions to read data, or to transmit an electric signal that causes a magnetic transition on the disc surface, to write data. The magnetic transducer includes a read/write gap that contains the active elements of the transducer at a position suitable for interaction with the magnetic surface of the disc. The

radial dimension of the gap fits within the radial extent of the data track containing the transitions so that only transitions of the single track are transduced by the interactive element when the interactive element is properly centered over the respective data track.

The magnetic transducer is mounted by a head structure to a rotary actuator arm and is selectively positioned by the actuator arm over a preselected data track of the disc to either read data from or write data to the preselected data track of the disc, as the disc rotates below the transducer. The actuator arm is, in turn, mounted to a voice coil motor that can be controlled to move the actuator arm across the disc surface.

A servo system is typically used to control the position of the actuator arm to insure that the head is properly centered over the magnetic transitions during either a read or write operation. In a known servo system, servo position information is recorded on the disc surface between written data blocks, and periodically read by the head for use in a closed loop control of the voice coil motor to position the actuator arm. Such a servo arrangement is referred to as an embedded servo system.

In modern disc drive architectures utilizing an embedded servo, each data track is divided into a number of data sectors for storing fixed sized data blocks, one per sector. Associated with the data sectors are a series of servo sectors, generally equally spaced around the circumference of the data track. The servo sectors can be arranged between data sectors or arranged independently of the data sectors such that the servo sectors split data fields of the data sectors.

Each servo sector contains magnetic transitions that are arranged relative to a track centerline such that signals derived from the transitions can be used to determine head position. For example, the servo information can comprise two separate bursts of magnetic transitions, one recorded on one side of the track centerline and the other recorded on the opposite side of the track centerline. Whenever a head is over a servo

sector, the head reads each of the servo bursts and the signals resulting from the transduction of the bursts are transmitted to, e.g., a microprocessor within the disc drive for processing.

When the head is properly positioned over a track centerline, the head will straddle the two bursts, and the strength of the combined signals transduced from the burst on one side of the track centerline will equal the strength of the combined signals transduced from the burst on the other side of the track centerline. The microprocessor can be used to subtract one burst value from the other each time a servo sector is read by the head. When the result is zero, the microprocessor will know that the two signals are equal, indicating that the head is properly positioned.

If the result is other than zero, then one signal is stronger than the other, indicating that the head is displaced from the track centerline and overlying one of the bursts more than the other. The magnitude and sign of the subtraction result can be used by the microprocessor to determine the direction and distance the head is displaced from the track centerline, and generate a control signal to move the actuator back towards the centerline.

Each servo sector also contains encoded information to uniquely identify the specific track location of the head. For example, each track can be assigned a unique number, which is encoded using a Gray code and recorded in each servo sector of the track. The Gray code information is used in conjunction with the servo bursts to control movement of the actuator arm when the arm is moving the head in a seek operation from a current track to a destination track containing a data field to be read or written.

The head structure also includes a slider having an air bearing surface that causes the transducer to fly above the data tracks of the disc surface due to fluid currents caused by rotation of the disc. Thus, the transducer does not physically contact the disc surface during normal

operation of the disc drive to minimize wear at both the head and disc surface. The amount of distance that the transducer flies above the disc surface is referred to as the "fly height." By maintaining the fly height of the head at an even level regardless of the radial position of the head, it is ensured that the interaction of the head and magnetic charge stored on the media will be consistent across the disc.

When writing or reading information, the hard disc drive may perform a seek routine to move the transducers from one cylinder (track) to another cylinder. During the seek routine the voice coil motor is excited with a current to move the transducers to the new cylinder location on the disc surfaces. The controller also performs a servo routine to insure that the transducer moves to the correct cylinder location, and is at the center of the track. This servo routine is typically comprised of three primary algorithms: a seek control algorithm, a transitional control algorithm, and a track following control algorithm. The seek control algorithm is used to rapidly move the read/write head of the disc drive to a desired track on the disc. The track following control algorithm is used to control the position and velocity of the read/write head so that the head remains over the center of the desired track. The transitional control algorithm is used to transition from the seek control algorithm to the track following control algorithm by sampling position and velocity error measurements and based on these measurements, determining whether control should be passed to the track following control algorithm. The transitional control algorithm and track following control algorithm are together sometimes referred to as the track following-settle system.

The transitional control algorithm is very critical so that the read/write head does not fall out of the final track follow stage during reading or writing due to initial position or velocity errors. Known transitional control algorithms sample position and velocity error measurements and compare them to established thresholds. The known

transitional control algorithm requires 8 consecutive samples whose position and velocity error measurements are within the established thresholds.

The position threshold, velocity threshold, and number of consecutive samples are used as the "tuners" for the track following settle system. That is, the values for the thresholds and number of consecutive samples may be adjusted to obtain different settling characteristics. However, it has been determined that adjusting these three parameters is not sufficient to provide acceptable read and write throughput performance.

Tightening the thresholds and increasing the number of consecutive samples for qualifying to transition to the track following control algorithm does provide low position and velocity errors, but it also increases the settle time unpredictably. This is because the consecutive sample based transitional algorithm may be restarted any number of times before the required number of consecutive samples falling within the established thresholds is encountered. That is, while accumulating the number of samples that fall within the established thresholds, if a sample exceeds a threshold, the count must be reset to zero and the process repeated, thus increasing the settle time for the read/write head.

The present invention provides a solution to this and other problems, and offers other advantages over previous solutions.

Summary of the Invention

The present invention provides a method and apparatus for improving the settle time and thus, the transition from seek control to track following control in a disc drive system. With the present invention, two counters are provided – a consecutive counter and a non-consecutive counter. The consecutive counter counts consecutive samples that meet

threshold requirements. The non-consecutive counter counts non-consecutive groups of consecutive samples that meet threshold requirements. When the consecutive counter reaches a first predetermined value, the non-consecutive counter is incremented and the consecutive counter is reset to zero. When the non-consecutive counter reaches a second predetermined value, a track following control mechanism is initiated to thereby transition from a seek control operation to a transitional control operation and finally a track following control operation.

These and various other features as well as advantages which characterize the present invention will be apparent upon reading of the following detailed description and review of the associated drawings.

Brief Description of the Drawings

FIG. 1 is an exemplary diagram of a disc drive in accordance with the present invention.

FIG. 2 is an exemplary block diagram of a printed circuit board and its electrical couplings in accordance with the present invention.

FIG. 3 is an exemplary diagram illustrating a control process for performing a seek operation.

FIG. 4 is an exemplary diagram illustrating the problem associated with consecutive settle criteria of known transitional control mechanisms.

FIG. 5 is an exemplary diagram illustrating an interaction of the primary operational elements in accordance with the present invention.

FIG. 6 is a flowchart outlining an exemplary operation of the present invention when performing a non-consecutive settle transitional control during a seek operation.

FIG. 7 is an exemplary diagram illustrating a distribution of settle times for a known consecutive settle transitional control mechanism.

FIG. 8 is an exemplary diagram illustrating a distribution of settle times for the non-consecutive settle transitional control mechanism of the present invention.

FIGs. 9A and **9B** are exemplary diagrams illustrating a comparison between the number of unsafe transitions for a known consecutive settle transitional control mechanism and the number of unsafe transitions for the non-consecutive settle transitional control mechanism of the present invention.

Detailed Description

The present invention is directed to a mechanism for controlling the transition from seek control to track following control during a seek operation of a disc drive system. As such, in order to provide a context in which the present invention may be implemented, a brief description of the disc drive system is provided with reference to **FIGs. 1** and **2**.

Referring now to the drawings, and initially to **FIG. 1**, there is illustrated an example of a disc drive designated generally by the reference numeral **20**. The disc drive **20** includes a stack of storage discs **22a-d** and a stack of read/write heads **24a-h**. Each of the storage discs **22a-d** is provided with a plurality of data tracks to store user data. As illustrated in **FIG. 2**, one head is provided for each surface of each of the discs **22a-d** such that data can be read from or written to the data tracks of all of the storage discs. The heads are coupled to a pre-amplifier **31**. It should be understood that the disc drive **20** is merely representative of a disc drive system utilizing the present invention and that the present invention can be implemented in a disc drive system including more or less storage discs.

The storage discs **22a-d** are mounted for rotation by a spindle motor arrangement **29**, as is known in the art. Moreover, the read/write heads **24a-h** are supported by respective actuator arms **28a-h** for controlled

positioning over preselected radii of the storage discs **22a-d** to enable the reading and writing of data from and to the data tracks. To that end, the actuator arms **28a-h** are rotatably mounted on a pin **30** by a voice coil motor **32** operable to controllably rotate the actuator arms **28a-h** radially across the disc surfaces.

Each of the read/write heads **24a-h** is mounted to a respective actuator arm **28a-h** by a flexure element (not shown) and comprises a magnetic transducer **25** mounted to a slider **26** having an air bearing surface (not shown), all in a known manner. As typically utilized in disc drive systems, the sliders **26** cause the magnetic transducers **25** of the read/write heads **24a-h** to "fly" above the surfaces of the respective storage discs **22a-d** for non-contact operation of the disc drive system, as discussed above. When not in use, the voice coil motor **32** rotates the actuator arms **28a-h** during a contact stop operation, to position the read/write heads **24a-h** over a respective landing zone **58** or **60**, where the read/write heads **24a-h** come to rest on the storage disc surfaces. As should be understood, each of the read/write heads **24a-h** is at rest on a respective landing zone **58** or **60** at the commencement of a contact start operation.

A printed circuit board (PCB) **34** is provided to mount control electronics for controlled operation of the spindle motor **29** and the voice coil motor **32**. The PCB **34** also includes read/write channel circuitry coupled to the read/write heads **24a-h** via the pre-amplifier **31**, to control the transfer of data to and from the data tracks of the storage discs **22a-d**. The manner for coupling the PCB **34** to the various components of the disc drive is well known in the art, and includes a connector **33** to couple the read/write channel circuitry to the pre-amplifier **31**.

Referring now to **FIG. 2**, there is illustrated in schematic form of the PCB **34** and the electrical couplings between the control electronics on the PCB **34** and the components of the disc drive system described above. A microprocessor **35** is coupled to each of a read/write control **36**, spindle

motor control **38**, actuator control **40**, ROM **42** and RAM **43**. In modern disc drive designs, the microprocessor can comprise a digital signal processor (DSP). The microprocessor **35** sends data to and receives data from the storage discs **22a-d** via the read/write control **36** and the read/write heads **24a-h**.

The microprocessor **35** also operates according to instructions stored in the ROM **42** to generate and transmit control signals to each of the spindle motor control **38** and the actuator control **40**. The spindle motor control **38** is responsive to the control signals received from the microprocessor **35** to generate and transmit a drive voltage to the spindle motor **29** to cause the storage discs **22a-d** to rotate at an appropriate rotational velocity.

Similarly, the actuator control **40** is responsive to the control signals received from the microprocessor **35** to generate and transmit a voltage to the voice coil motor **32** to controllably rotate the read/write heads **24a-h**, via the actuator arms **28a-h**, to preselected radial positions over the storage discs **22a-d**. The magnitude and polarity of the voltage generated by the actuator control **40**, as a function of the microprocessor control signals, determines the radial direction and radial speed of the read/write heads **24a-h**.

When data to be written or read from one of the storage discs **22a-d** are stored on a data track different from the current radial position of the read/write heads **24a-h**, the microprocessor **35** determines the current radial position of the read/write heads **24a-h** and the radial position of the data track where the read/write heads **24a-h** are to be relocated. The microprocessor **35** then implements a seek operation wherein the control signals generated by the microprocessor **35** for the actuator control **40** cause the voice coil motor **32** to move the read/write heads **24a-h** from the current data track to a destination data track at the desired radial position.

When the actuator has moved the read/write heads **24a-h** to the destination data track, a multiplexer (not shown) is used to couple the head **24a-h** over the specific data track to be written or read, to the read/write control **36**, as is generally known in the art. The read/write control **36** includes a read channel that, in accordance with modern disc drive design, comprises an electronic circuit that detects information represented by magnetic transitions recorded on the disc surface within the radial extent of the selected data track. As described above, each data track is divided into a number of data sectors.

During a read operation, electrical signals transduced by the head from the magnetic transitions of the data sectors are input to the read channel of the read/write control **36** for processing via the pre-amplifier **31**. The RAM **43** can be used to buffer data read from or to be written to the data sectors of the storage discs **22a-d** via the read/write control **36**. The buffered data can be transferred to or from a host computer utilizing the disc drive for data storage.

As previously mentioned, the present invention provides a mechanism for improving the settle time during a transitional control stage of a seek operation. **FIG. 3** is an exemplary diagram illustrating a control process for performing a seek operation. As shown in **FIG. 3**, the control process involves a seek control portion **310** which is used to rapidly bring the read/write head to a position relatively close to the desired track on the disc. Once the read/write head is within a tolerance of the desired track, control passes to the transitional control portion **320** which is used to control the read/write head so that it settles over the center of the desired track. Once a predetermined criteria is satisfied, e.g., a predetermined number of samples of position and velocity errors fall within given thresholds, the control is passed to the track following control portion **330** which maintains the position and velocity of the read/write head relative to the desired track.

As previously mentioned, in known systems, the transitional control portion **320** takes samples of the position and velocity error, i.e. the difference between a measured position and velocity and a desired position and velocity, to determine if a predetermined number of consecutive samples fall within established thresholds. Only when the predetermined number of consecutive samples fall within established thresholds is the control passed to the track following control portion **330**.

This approach has a number of drawbacks some of which have been touched on above. First, because of the rigid nature of the requirement, the count of the number of consecutive samples falling within the established threshold may be restarted multiple times before a group of consecutive samples is identified that meet the requirements. This problem is illustrated in **FIG. 4**. The example shown in **FIG. 4** is for a consecutive settle criteria of 8 samples between the designated thresholds. As shown in **FIG. 4**, a plurality of samples may be taken that fall within the predetermined thresholds but may not be enough to satisfy the consecutive settle criteria. That is, as shown, there may be 7 samples that all fall within the established thresholds but an eighth sample may exceed the thresholds. This may be due to noise, for example.

Once this eighth sample is determined to have exceeded the thresholds, the number of consecutive samples falling within the established thresholds is reinitialized to zero and the process must repeat. Thus, it may take many samples and a much longer time for the transitional control portion to determine that the read/write head has settled to a point that control may be passed to the track following control portion.

Another drawback to the known consecutive settle criteria based transitional control systems is that the number of unsafe track following control transitions made is relatively large. An unsafe track following control transition (or simply an "unsafe") is a transition to the track

following control portion which eventually results in the control falling out of the track following control portion. That is, the position error and/or velocity error become large enough that the track following control portion cannot adequately handle it and control must be returned to the transitional control portion. This may result in write failures, for example.

The present invention avoids the problems of the known transitional control algorithms due to the retriggering of the consecutive settle counter because sampled position or velocity errors exceed established thresholds. The present invention avoids these problems by providing a mechanism by which the number of retriggers experienced before transitioning to the track following control portion is reduced.

The mechanism of the present invention includes both a consecutive settle counter (or simply consecutive counter) and a non-consecutive settle counter (or simply non-consecutive counter). The combination of these two counters is used to determine when the control of the read/write head may be passed to a track following control algorithm from the transitional control algorithm. That is, the counters may be set to identify the number of non-consecutive groups of consecutive samples that must have position and/or velocity errors within the predetermined threshold(s). Thus, rather than merely requiring a certain number of consecutive samples that fall within the thresholds, the present invention provides a mechanism for loosening these requirements by allowing for a certain number of non-consecutive groups of consecutive samples to be the instigator of the track following control algorithm.

With the present invention, samples of position and/or velocity errors are taken in a manner generally known in the art. The position and/or velocity errors are compared to thresholds that are established, for example, during calibration of the disc drive. If the position and/or velocity error falls within the established thresholds, i.e. does not meet or exceed the thresholds, then the consecutive counter is incremented.

The consecutive counter and the non-consecutive counter have upper values, or settle criteria, which identify when an event is triggered. For example, the consecutive counter has an upper value or settle criteria that triggers incrementing of the non-consecutive counter. The non-consecutive counter has an upper value or settle criteria that triggers the transition of the control of the read/write head to the track following control portion **330**. When the upper value or settle criteria of the consecutive counter is met, the non-consecutive counter is incremented. Once the non-consecutive counter requirements are met, i.e. the upper value or settle criteria of the non-consecutive counter is met, then the control of the read/write head is passed to the track following control portion **330**.

With the combination of the consecutive counter and the non-consecutive counter, various arrangements of settle criteria may be established based on the particular implementation of the present invention. For example, with the present invention, the number of consecutive samples falling within the thresholds may be set to 1 and the number of non-consecutive groups of samples falling within the thresholds may be set to 14. As a result of this combination of settle criteria, each sample whose position and/or velocity error falls within the established thresholds will cause the consecutive counter to increment. Since the requirement of the consecutive counter is that there be 1 consecutive sample that falls within the established thresholds, then when the consecutive counter is incremented, the non-consecutive counter is also incremented. Once the non-consecutive counter reaches its requirement of 14, the control operation is passed to the track following control portion. Thus, with this particular setting of counter criteria, any 14 consecutive or non-consecutive samples falling within the established threshold will satisfy the settle requirements for transitioning control to the track following control portion.

As another example, assume that the consecutive counter requirement is set to 2 and the non-consecutive counter requirement is set to 8. This may be referred to as requiring 8 non-consecutive groups of 2 samples whose position and/or velocity errors are within the established thresholds. Thus, the non-consecutive counter is only incremented when the consecutive counter reaches a count of 2. Once the consecutive counter reaches 2, the consecutive counter is reinitialized to zero and the non-consecutive counter is incremented by 1. Once the non-consecutive counter reaches a count of 8, the control is transitioned to the track following control portion. Other combinations of consecutive counter requirements and non-consecutive counter requirements may be used without departing from the spirit and scope of the present invention.

FIG. 5 is an exemplary diagram illustrating an interaction of the primary operational elements in accordance with the present invention. The operational elements shown in **FIG. 5** may be implemented as hardware, software, or any combination of hardware and software. In a preferred embodiment, the operational elements are implemented as software instructions executed by one or more processors. For example, the operational elements of **FIG. 5** may be software instructions executed by the actuator controller **40** of **FIG. 2**. Alternatively, the operational elements of **FIG. 5** may be implemented as circuitry in the actuator controller **40** or separate circuitry on the printed circuit board **34** of **FIG. 2**.

As shown in **FIG. 5**, sampled data, such as position and/or velocity error data is input to a comparator **510**. The sampled data is compared to threshold information obtained from a threshold(s) established during a calibration of the disc drive. The results of the comparison by the comparator **510** are output to the consecutive counter **520**. These results may be either a signal indicating that the sample data is within the threshold(s) or is outside the threshold(s).

Based on the results output by the comparator **510**, the consecutive counter **520** may either increment itself or reset to a zero value. If the consecutive counter **520** receives results from the comparator **510** indicating that the sample data is within the threshold(s), then the consecutive counter **520** is incremented. If the consecutive counter **520** receives results from the comparator **510** indicating that the sample data is outside the threshold(s), then the consecutive counter **520** is reset to zero.

In addition to the above, the consecutive counter **520** determines if it has reached an upper limit or settle criteria. If the upper limit or settle criteria is reached by the consecutive counter **520**, a settle criteria met signal is sent to the non-consecutive counter **530**. The consecutive counter **520** is then reset to zero.

The non-consecutive counter **530**, upon receiving a settle criteria met signal from the consecutive counter **520**, increments itself. The non-consecutive counter **530** then determines if an upper limit or settle criteria established for the non-consecutive counter **530** has been reached. If so, a transition to track following signal is sent to a seek operation controller **540**. The seek operation controller **540**, upon receiving the transition to track following signal, begins controlling the position and velocity of the read/write head using a track following control algorithm.

FIG. 6 is a flowchart outlining an exemplary operation of the present invention when performing a non-consecutive settle transitional control during a seek operation. It will be understood that each block of the flowchart illustration, and combinations of blocks in the flowchart illustration, can be implemented by computer program instructions. These computer program instructions may be provided to a processor or other programmable data processing apparatus to produce a machine, such that the instructions which execute on the processor or other programmable data processing apparatus create means for implementing the functions specified in the flowchart block or blocks. These computer program

instructions may also be stored in a computer-readable memory or storage medium that can direct a processor or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable memory or storage medium produce an article of manufacture including instruction means which implement the functions specified in the flowchart block or blocks.

Accordingly, blocks of the flowchart illustration support combinations of means for performing the specified functions, combinations of steps for performing the specified functions and program instruction means for performing the specified functions. It will also be understood that each block of the flowchart illustration, and combinations of blocks in the flowchart illustration, can be implemented by special purpose hardware-based computer systems which perform the specified functions or steps, or by combinations of special purpose hardware and computer instructions.

As shown in **FIG. 6**, the operation starts by taking the next sample measurement of the position and/or velocity error of the read/write head (step **610**). The position and/or velocity error are compared to established threshold(s) (step **620**) and a determination is made as to whether the position and/or velocity error are within the established threshold(s) (step **630**). If not, the consecutive counter is rest (step **635**) and the operation returns to step **610**. Otherwise, if the position and/or velocity error is within the established threshold(s), the consecutive counter is incremented (step **640**).

A determination is then made as to whether the consecutive counter requirements have been met (step **650**). That is, it is determined whether the upper limit or settle criteria established for the consecutive counter are achieved by the current count of the consecutive counter. If not, the operation returns to step **610**. If the consecutive counter requirements have been met, then the non-consecutive counter is incremented (step **660**).

A determination is then made as to whether the non-consecutive counter requirements have been met (step **670**). That is, it is determined whether the upper limit or settle criteria established for the non-consecutive counter are achieved by the current count of the non-consecutive counter. If not, the consecutive counter is reset (step **635**) and the operation returns to step **610**. If the non-consecutive counter requirements are met, the track following control is initiated (step **680**).

Thus, the present invention provides a mechanism by which the instigator for transitioning control to a track following algorithm is a predetermined number of non-consecutive groups of consecutive samples meeting threshold requirements. Because the present invention allows for non-consecutive groups to satisfy the requirements for transitioning to a track following control algorithm, the settle time distribution tends to be much more consistent for the present invention as opposed to the consecutive settle criteria of known systems.

FIG. 7 is an exemplary diagram illustrating a distribution of settle times for a known consecutive settle transitional control mechanism. As shown in **FIG. 7**, the settle time for various seek lengths where the seek is from either the inner diameter (ID) to the outer diameter (OD) or vice versa, tends to be scattered between 4 and 18 ms. For example, as shown in **FIG. 7**, the seek times experienced for a seek length of 2×10^4 tracks, range from approximately 7 ms to 18 ms. In addition, the number of unsafes, i.e. the number of transitions to the track following control algorithm that result in the read/write head falling out of track following and causing write faults, is quite large (6654 seeks with write faults in the depicted example).

FIG. 8 is an exemplary diagram illustrating a distribution of settle times for the non-consecutive settle transitional control mechanism of the present invention. As shown in **FIG. 8**, the seek times are not as scattered for the non-consecutive settle transitional control mechanism of the present

invention when compared to the consecutive settle control mechanism of the known system illustrated in **FIG. 7**. For example, for a seek length of $2x10^4$ tracks, the seek time is between approximately 7.5 ms and 10 ms. Moreover, the number of unsafes is reduced to less than half of those shown in **FIG. 7**.

FIGs. 9A and **9B** are exemplary diagrams illustrating a comparison between the number of unsafe transitions for a known consecutive settle transitional control mechanism and the number of unsafe transitions for the non-consecutive settle transitional control mechanism of the present invention. As shown in **FIG. 9A**, the percentage of seeks that were unsafe in relation to the percentage of the stroke is quite large for every distance measurement in the known consecutive settle criteria based control mechanism. However, as shown in **FIG. 9B**, for the non-consecutive settle criteria based control mechanism, there are distances where there are no unsafe seeks and the distances where there are unsafe seeks (with the exception of the spike appearing at approximately 85-90% stroke) tend to have a smaller number of unsafe seeks than the consecutive settle criteria based control mechanism. The average percentage of unsafe seeks for the known consecutive settle criteria based control mechanism is approximately 10.26% of the seeks while the average percentage of unsafe seeks for the non-consecutive settle criteria based control mechanism of the present invention is approximately 0.06% of the seeks.

Thus, by using a the non-consecutive settle criteria of the present invention, increased throughput of the disc drive system may be achieved by reducing the amount of settle time and making the settle time more consistent between seek operations of the same length. In addition, the number of unsafe seeks is reduced dramatically thereby reducing the number of write failures of the disc drive system.

It is important to note that while the present invention has been described in the context of a fully functioning data processing system,

those of ordinary skill in the art will appreciate that the processes of the present invention are capable of being distributed in the form of a computer readable medium of instructions and a variety of forms and that the present invention applies equally regardless of the particular type of signal bearing media actually used to carry out the distribution. Examples of computer readable media include recordable-type media, such as a floppy disc, a hard disc drive, a RAM, CD-ROMs, DVD-ROMs, and transmission-type media, such as digital and analog communications links, wired or wireless communications links using transmission forms, such as, for example, radio frequency and light wave transmissions. The computer readable media may take the form of coded formats that are decoded for actual use in a particular data processing system.

The description of the present invention has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order to best explain the principles of the invention, the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.